RESEARCH HIGHLIGHT
Basic Sciences Program
Geosciences Subprogram

Project: What does an instrument measure? Empirical spatial weighting functions calculated from permeability data sets measured on multiple sample supports

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Objectives: Here, we empirically address the question, "what does an instrument measure?" By measure we mean the sample support or sample volume associated with an instrument, as well as, how the instrument spatially weights the heterogeneities comprising that sample support.

Results: Analyses were performed on a set of 13,824 permeability measurements collected from a block of Berea Sandstone. Spatially exhaustive permeability data sets were acquired from each block face with a computer automated minipermeameter test system. Key to our investigation was the use of different sized tip seals (Figure a) allowing measurements to be made over different sample supports. The measurement characteristics of the minipermeameter were explored by way of linear filter analysis. In this model the measurement characteristics of the instrument are expressed by the spatial weighting function. Accordingly, our analyses are based on the calculation of empirical spatial weighting functions that relate 576 permeability data acquired at one sample support (i.e., tip seal) with the same number of data collected at another larger support. Results indicate that the empirical weighting functions (Figure b) are consistent with the basic physics of the minipermeameter measurement. First, the calculated weighting functions are centered on the measurement, consistent with the symmetry of the tip seal. Second, the weighting functions decay as a non-linear function of radial distance from the center of the tip seal, consistent with the divergent flow geometry imposed by the minipermeameter. Third, the magnitude of the weighting function decreases while its breadth increases with increasing tip seal size, reflecting the increasing sample support. In our analysis we further demonstrate, both empirically and theoretically, that non-additive properties like permeability are amenable to linear filter analysis under certain limiting conditions (i.e., small variances).

Significance: Constitutive properties, like permeability, are very sensitive to their conditions of measurement; however, models and physical data for characterizing an instrument's measurement are currently limited. Here, we present rare empirical data characterizing a hydraulic instrument's measurement of a heterogeneous porous material. The insight gained from these tests not only apply to minipermeameters but other hydraulic instruments (e.g., pump, slug, and tracer tests) as well.

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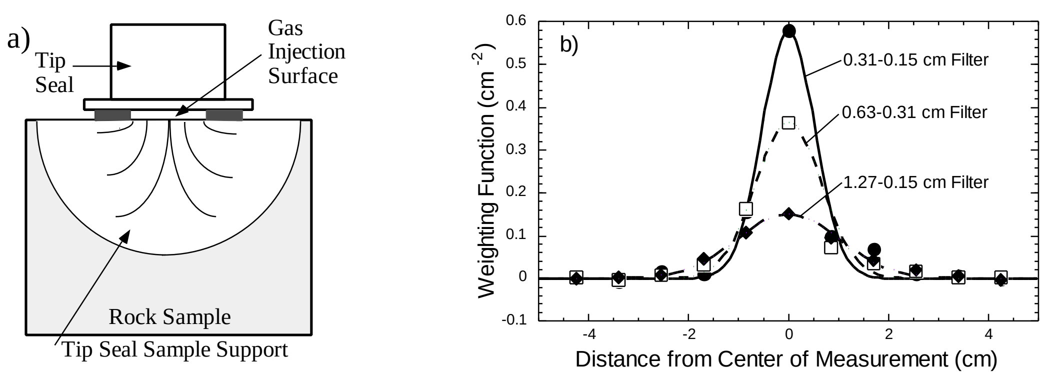

Figure: (a) Schematic of the gas flow field imposed by a minipermeameter measurement (note that four different size tip seals were used in our testing). (b) Three empirical weighting functions (symbols) calculated from permeability data measured with different size tip seals (denoted by inner tip seal radius). Although 2-D weighting functions were calculated, 1-D transects are presented here to facilitate comparison. An isotropic Gaussian model has been fit to each transect (solid lines).